

9 Control Surveys

Control surveys establish a common, consistent network of physical points that are the basis for controlling the horizontal and vertical positions of transportation improvement projects and facilities. Corridor control surveys ensure that adjacent projects have compatible control. Project control surveys provide consistent and accurate horizontal and vertical control for all subsequent project surveys — photogrammetric, mapping, planning, design, construction, and right of way.

The following policies, standards, and procedures are applicable to all control surveys for Caltrans-involved transportation improvement projects. This includes surveys performed by Caltrans survey staff, Caltrans consultants, local agencies, private developers and others.

In 1991, Caltrans in cooperation with the National Geodetic Survey (NGS) and others, established a California high-precision geodetic network to meet the following needs:

- Global Positioning System (GPS) survey methods.
- Today's multi-organizational transportation project development efforts.
- Surveys required to accurately locate transportation improvements and rights of way.
- Geographic Information Systems (GIS).

This network is called the California High-Precision Geodetic Network (HPGN). In other states, similar networks are often referred to as High-Accuracy Reference Networks (HARN).

The HPGN established 238 Order B (relative position accuracy of 0.8 centimeter plus one part in a million) horizontal control stations along transportation corridors throughout California using GPS survey methods. The stations are spaced about 64 kilometers apart on a grid-like network and form the basis for all Caltrans control surveys. Subsequently, corridor control surveys have been undertaken to establish a densified network (HPGN-D) of corridor control with stations spaced about 16 kilometers apart along State highways.

9.1 General Policy

Horizontal corridor control surveys shall be performed along transportation corridors where multiple improvement projects are planned.

Horizontal project control surveys shall be performed for all Caltrans-involved transportation improvement projects using California Coordinate System coordinates to define the geographic positions of project facilities.

Vertical project control surveys shall be performed for each Caltrans-involved transportation improvement project that requires elevations to define the positions of fixed works.

Horizontal project and corridor control surveys should be based on (tied and adjusted to) three or more HPGN or HPGN-D stations. If a Horizontal Project Control Survey network “tie” to the nearest HPGN station or HPGN-D station exceeds 20 kilometers, establishment of additional HPGN-D station(s) shall be considered. See Section 4.1, “Horizontal Datum” and Section 9.4-2, “Horizontal Corridor Control (HPGN-D) Surveys.”

When feasible, horizontal project control shall be established using GPS surveys complying with Caltrans first-order accuracy standard. When GPS survey methods cannot be used for all or part of a Horizontal Project Control Survey, a Total Station Survey System (TSSS) traverse network meeting the Caltrans second-order accuracy standard is acceptable. See Section 5, “Classifications and Accuracy Standards.”

Vertical project control surveys shall be based on a single, common vertical datum to ensure that various phases of a project and contiguous projects are consistent. The preferred vertical datum for Caltrans-involved improvement projects is the North American Vertical Datum of 1988 (NAVD88). See Section 4.2, “Vertical Datum,” for a description of NAVD88 and exceptions to its use. All vertical project control survey work will be done to at least the Caltrans third-order survey accuracy standard. See Section 5, “Classification and Accuracy Standards.”

9.2 Planning and Research

Responsibility

The planning and design phases of the project development process require appropriate mapping and field surveys. Project control surveys provide the basis and framework for base maps and digital terrain models used in the development of contract plans and acquisition of right of way. As soon as a project requiring Surveys involvement is known, e.g., appears on the “Status of Projects” report or an initial survey request is received, a Project Surveyor should be appointed by the District Surveys Engineer. The Project Surveyor should be an active participant on the Project Development Team to provide advice and input on survey related matters and issues, be responsible for initiating control surveys, and respond to project survey needs.

Planning

The Project Surveyor is responsible for planning and establishing the project control network. Project control surveys should be planned to provide convenient horizontal and vertical survey control for right of way engineering, photogrammetric mapping, engineering, construction, and monumentation surveys for the duration of the project. A work plan for establishing the project control should be developed after consulting the following individuals:

- Project Manager
- Project Engineer
- District Survey Engineer
- District Right of Way Engineer
- District Photogrammetry Coordinator

Planning the control network so that it will meet the needs of all subsequent project surveys is critical. Key steps in the control planning process are to:

- Ascertain the need for additional corridor control
- Develop a survey work schedule that meets the needs of the Project Development schedule.
- Research the existing horizontal and vertical control networks.

- Recover and evaluate existing control.
- Decide on the vertical datum for the project (NAVD88 preferred).
- Plan the project control network and select the methods for establishing control.
- Plan supplemental control.

If possible, project control should be planned so that project control monuments serve for both horizontal and vertical control. It is important that project control plans consider the need for supplemental control.

Research

The Project Surveyor will conduct a thorough search of Caltrans records to determine the availability of existing control in the project area. Every attempt should be made to use existing Caltrans control in the area. A computer program for conversions should never be used to convert NAD27 horizontal control to the NAD83 datum. New coordinate values, based on the HPGN, should be determined for existing control using field observations and network adjustments. See Section 4.3-3, "Coordinate Conversion." All horizontal control, including conversions of existing control, should be based on the HPGN. Another source of control information is the NGS.

For vertical control, research may be expanded beyond Caltrans surveys files and NGS to include other State, Federal, County and local agencies.

9.3 Office Preparation

The Project Surveyor, in consultation with the field supervisor and party chief, is responsible for the development of the necessary instructions and information (field package) for performing required control surveys. Surveys office staff, under the direction of the Project Surveyor, generally prepare a field package using information obtained from research, together with other compiled and computed data. Field packages should contain all the necessary information and data to efficiently complete the field work required for establishment of control networks. Typical information to include in the field package is:

- Expenditure authorization and time recording sheet information.
- Copy of the original survey request.
- Right of entry information, conditions, and permits.

- Criteria for selection of survey method.
- Predetermined positions of control monuments and anticipated project alignments.
- Copies of pertinent research materials (record of survey maps, parcel maps, tract maps, and subdivision maps).
- Caltrans right of way and monumentation maps.
- Existing aerial photographs.
- Station “to reach” information.
- Reference ties and related data for existing horizontal control monuments.
- Verical control monument locations, descriptions, and elevations.

9.4 Field Work

9.4-1 Reconnaissance

Prior to initiating a Control Survey a thorough search and recovery of existing horizontal and vertical control monuments in the immediate area of the project is required. Also, a field reconnaissance will be required before final control net planning is accomplished and field work is begun. Recovered control monuments must be evaluated before being used as a basis for new control surveys. All recovered points should be fully described in the survey notes.

9.4-2 Horizontal Corridor Control (HPGN-D) Surveys

Corridor control surveys are undertaken to establish HPGN-D stations spaced along highway corridors approximately 16 kilometers apart. These control stations, together with the HPGN stations, are used as basic control for all of Caltrans surveying efforts. HPGN and HPGN-D stations, where established, have become the accepted horizontal control network for California surveyors, ensuring consistency between surveys performed by Caltrans and others.

Each District/Region should develop a systematic plan for completing corridor control/HPGN-D surveys. District-wide or area-wide HPGN-D surveys are the preferred method for establishing corridor control. When large area densification surveys are planned, cooperative agreements for performing the work should be established with local agencies and

private sector surveyors. This will ensure that the HPGN-D stations are accepted as the “best” control for the local surveying community.

When ties to HPGN stations, for purposes of establishing project control are longer than 20 kilometers, an HPGN-D station should be established in conjunction with project control. Exceptions to this policy shall be determined by the District Surveys Engineer based on current and future project development needs and available resources.

Method

Corridor control surveys must be performed using GPS surveys. See Section 6, “Global Positioning System (GPS) Survey Specifications.”

Note: Survey procedures and documentation must conform to NGS specifications if survey results will be submitted to NGS for inclusion in the National Spatial Reference System (NSRS).

Accuracy

Surveys must be referenced and adjusted to HPGN stations and meet Caltrans first-order survey standards with a distance accuracy standard of 1:500,000. See Section 5, “Classification and Accuracy Standards” (See Figure 5-1, Note 10).

Monumentation

Monuments shall be located along transportation corridors in secure locations. The station site shall be selected with safety considerations for the surveyor and others given highest priority. Sites within or adjacent to the traveled way of limited access highways should be avoided. Monuments shall be accessible to the public, preferably in a public right of way or easement. Typical locations are:

- Along freeway ramps near the junction of the right of way for the ramp and the local street.
- Within county or city street right of way.
- Bridge abutments (if on piles).
- On public property or at public facilities (canals, parks, etc.).

Whenever possible select station locations that can be easily described. When several locations are equally satisfactory choose the one that is near features that will aid in future monument recovery.

Monuments shall be constructed to ensure permanency. Monument type shall be chosen to suit the local conditions. Acceptable monuments are as follows:

- NGS class B rod marks. See *NOAA Manual NOS NGS 1, Geodetic Bench Marks*.
- Existing NGS monuments in good condition and equal to or exceeding the permanency provided by class B rod marks.
- Other existing or new monuments, if they meet or exceed the permanency of class B rod marks and are approved by the Geometronics Branch.
- A disk epoxied into a drilled hole in a large rock mass (large boulders are not acceptable).
- A disk epoxied into a drilled hole in a concrete bridge abutment on piles (not on the bridge deck or an abutment fill) or other permanent and stable concrete structure.

If the survey results will be included in the NSRS, use monument disks specifically designed and manufactured for HPGN-D surveys stamped with the calendar year of the survey and the station identification. If another agency is the primary sponsor of the densification survey be sure that the disks used are stamped with the notation "HPGN-D."

9.4-3 Horizontal Project Control Surveys

Horizontal project control surveys establish control for transportation improvement projects. All subsequent horizontal surveys for a project are based on the horizontal project control.

Methods

Whenever feasible, horizontal project control shall be established using GPS survey methods. See Section 6, "Global Positioning System (GPS) Survey Specifications." When GPS survey methods cannot be used for all or part of a horizontal project control survey, the TSSS system can be used. See Section 7, "Total Station Survey System (TSSS) Survey Specifications."

Some horizontal project control surveys are hybrid projects with TSSS networks bracketed by GPS azimuth pairs at the beginning, end, and at intervals throughout the project.

Accuracy

Horizontal project control surveys must be referenced and adjusted to HPGN and/or HPGN-D stations. Preferred order of accuracy is Caltrans first-order survey standards with a distance accuracy standard of 1:100,000. Caltrans second-order accuracy standard (1:20,000) is acceptable when using the TSSS method.

Monumentation

- Establish sufficient monuments so that a minimum of three monuments exist for each project.
- Set monuments as required by project conditions, generally no more than 800 meters apart. If longer spacing is used, establish monuments in pairs for intervisibility. Minimum, spacing for monuments is 150 meters (300 meters when using GPS).
- Locate monuments to minimize disturbance by construction and to be clear of traffic and accessible, preferably within a public right of way or easement.
- Preferably, locate monuments so they are intervisible with at least two other monuments.
- Establish durable, permanent monuments with Caltrans markings. The preferred monument is the Type “A” concrete monument with metal disk shown on Standard Plan A74. Other acceptable monuments are 50 mm galvanized steel pipe 750 mm long, with brass disk or plastic plug, 16 mm rebar, 750 mm long with cap, metal disk epoxyed in rock mass or bridge abutment, existing stable monuments, etc.

9.4-4 Vertical Project Control Surveys

A vertical project control survey shall be performed for each specific Caltrans-involved transportation improvement project that requires elevations to define topographic data points or positions of fixed works. The establishment of vertical project control monuments is important because all subsequent project surveys requiring elevations are to be based on the vertical project control.

When feasible, vertical control for projects should be established at all horizontal control stations. Additional benchmarks should be set to densify vertical control to provide convenient control for photogrammetry, topographic, and construction purposes.

Method

Vertical Project Control can be established using the following methods:

- Differential leveling, see Section 8, “Differential Leveling Survey Specifications.”
- Trigonometric leveling, see Section 7 “Total Station Survey System (TSSS) Survey Specifications.”
- GPS can be used to bring NAVD88 to a project. See Section 6.9-2, “Vertical GPS Surveys — Applications.”

Accuracy

Preferred accuracy standard is Caltrans second-order survey accuracy, although Caltrans third-order accuracy is acceptable. See Section 5, “Classifications and Accuracy Standards.”

Monumentation

- Monuments should be spaced as required by project conditions, generally no more than 500 meters apart.
- Whenever feasible, utilize horizontal project control monuments as vertical control monuments.
- Locate monuments to minimize disturbance by construction and to be clear of traffic and accessible, preferably within a public right of way or easement.
- When feasible, establish a monument at each major structure.
- Establish durable, permanent monuments with Caltrans markings. The preferred monument is the Type “A” concrete monument with metal disk shown on Standard Plan A74. Other acceptable monuments are 50 mm galvanized steel pipe 750 mm long, with brass disk or plastic plug, 16 mm rebar, 750 mm long with cap, metal disk epoxied in rock mass or bridge abutment, existing stable monuments, etc.

9.4-5 Supplemental Control

Supplemental control surveys are undertaken to densify project control surveys. Supplemental control is used for establishing photogrammetric control, locating terrain data for engineering surveys, establishing setup points for construction staking, locating land net monuments, and setting right of way monuments. Supplemental control points may be used for both horizontal and vertical control.

Method

- Differential leveling, see Section 8, “Differential Leveling Survey Specifications.”
- TSSS surveys, see Section 7 “Total Station Survey System (TSSS) Survey Specifications.”
- Global Positioning System, see Section 6 “Global Positioning System (GPS) Survey Specifications.”

Accuracy

Supplemental control surveys shall meet Caltrans third-order survey accuracy for both horizontal and vertical control. See Section 5, “Classifications and Accuracy Standards.”

Monumentation

Generally monumentation for supplemental control is temporary. Monuments should be set where needed, but out of the way of construction and in stable ground. Examples of temporary monuments are: spikes, concrete nails, iron pipes, rebar, etc.

9.5 Office Data Processing and Documentation

All control surveys will be evaluated, checked and adjusted by method of least squares before being used as a basis for any project survey.

The project surveyor is responsible for assembling all research materials along with the completed field data into a project control survey file. The file is then evaluated by:

- Reviewing field notes for completeness and accuracy.
- Reviewing all closures (residuals), adjustments, and conformance to standards.
- Calculating final horizontal and vertical positional values.

9.5-1 Project Control Diagram

The Project Surveyor shall prepare a project control diagram for each horizontal project control survey. The diagram shall be a schematic drawing of the horizontal network, including a north arrow, title block, survey date, date of diagram preparation, legend and

vicinity map, if applicable. The diagram shall show the horizontal control monuments established, and the HPGN and HPGN-D stations that were used as the basis for the survey with appropriate symbols, monument names, and coordinate table reference numbers, if applicable. Vertical control monuments shall be shown in their location on the diagram.

The project control diagram shall include a note that bearings, distances, and coordinates are based on the California Coordinate System and another note naming the datum used for vertical control. The California Coordinate System note shall state the zone of the system, project mapping angle(s), and project combination factor(s).

The project control diagram should contain a coordinate table which includes the following:

- Monument names.
- Horizontal coordinates of each monument (N,E).
- Least squares adjustment residuals for new control points.
- Coordinate dates (epochs).
- Descriptions of each monument.
- Bearing and distances of observed lines (if applicable).
- Reference to permanent file location of survey data, including "to reach" information.
- Overall network closure ratio.

The diagram shall also show the approximate location and include a table listing all vertical project control monuments, including the following:

- Vertical control monument.
- Elevation of each monument.
- Order of accuracy of vertical net.
- Least squares adjustment residuals, if applicable, for new vertical control points.
- Basis of the vertical control surveys (i.e., reference vertical control monuments).
- Descriptions of each monument.

The project control diagram shall be retained (archived) as part of the project control report.

9.5-3 Project Control Report

The Project Surveyor shall prepare a project control report for each project control survey and file the report, with the project control diagram, as part of the permanent survey office records for the project. Cross file references shall be established in the Surveys office which will enable retrieval of project control reports by either (i) Expenditure Authorization, (ii) County, Route, and Kilopost, and (iii) by the California Coordinate System coordinates.

Project control reports should generally not exceed three pages plus attachments. The following should be included in each report:

Project Identification: County, route, kilopost, E.A., etc.

Project Surveyors: Project Surveyor, Field Supervisor, Party Chief, Office Supervisor, Data Processor; include Land Surveyor license numbers as applicable.

Survey Specifications/Standards: Statement regarding the specifications and standards used for the survey; i.e., Caltrans second-order class, dated nn/nn/nn.

Dates of Survey: Dates field work began and ended and date final adjustments were completed.

Horizontal Survey Method: General description of the survey method used: i.e., static, kinematic, station-observation time, etc.

Vertical Survey Method: General description of instrumentation used: i.e., bar code, TSSS, three-wire, etc.

Horizontal Monument Types: General description.

Vertical Monument Types: General description.

Instruments: Manufacturer, model, serial number of GPS receivers, type and serial numbers of antenna used, digital level, TSSS, etc.

Baseline Software: Name and version of software used to produce baseline vectors and method of data reduction

Adjustments: Least squares software used, general comments regarding the consistency of accuracy's achieved, explanation of any large residuals, etc.

Field Comments: Pertinent comments regarding the field surveys: i.e., right of entry problems, observation problems, explanation of delays, etc.

Office Comments: Pertinent, general comments regarding the data processing and adjustment.

Project Control Diagram: The Project Control Diagram shall be included as an attachment to the Project Control Report.

The project surveyor in charge of the project control survey shall be responsible for signing, sealing, and submitting all documents relevant to the project control survey for archiving.

9.5-4 Special Consideration for Corridor Control (HPGN-D) Surveys

Corridor control surveys should be coordinated with the Geometronics Branch. Each corridor control survey shall be either submitted to NGS for inclusion in the National Spatial Reference System (NSRS) or be filed with the County Surveyor as a Record of Survey. The preferred method is to submit the survey for inclusion in the NSRS, so that all HPGN-D stations will be included in the NSRS and any future NGS adjustments. For requirements for submittal to NGS, see *Input Formats and Specifications of the National Geodetic Survey Data Base, I. Horizontal Control Data*, National Geodetic Survey.